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ABSTRACT

This booklet provides suggestions for student activities appropriate for introducing ideas about forces and their relationship to motion at the Form 1 to 4 level. The overall program is divided into five parts and is based on knowledge of views about force, friction, and gravity which children bring with them to science classrooms. An overview of the program is provided and, in separate sections, the aims and strategies are set forth, and student materials (worksheets, activity sheets, surveys, and others) for each individual part are presented. Students' views about force are determined in part 1. Momentum and momentum changes are investigated in part 2. "Pushes" and "pulls" are examined in part 3. Total force is studied in part 4. Part 5 investigates how some children's ideas have been modified by the learning experiences provided in the previous parts and provides opportunities, if necessary, for further remediation. (Scientists' answers to survey questions and a mathematics activity on force/momentum are found in appendices.) (JN)

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TEACHING ABOUT FORCE

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WORKING PAPER 34

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1981

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TEACHING ABOUR FORCE - SUGGESTED TEACHING ACTIVITIES

Brendan Schollum, Graham Hill and Roger Osborne (Editors) [1]

This booklet is about getting children to understand some of the basic ideas held by scientists about force and its effects on motion. The teaching approach attempts to build on, rather than ignore, the ideas about force and motion that children have acquired from a young age.

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University of Waikato

November 1981

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[1] This work has developed from the work of the Physics-Action Research Group of the Learning in Science Project. The rationale behind the activities and details of the work done by the Group can be found in LISP Working Paper No. 32. If you have any suggestions on how the Unit can be improved please write to Roger Osborne, University of Waikato.

INTRODUCTION TO THE BOOKLET

One of the central ideas in introductory science is the notion of force. Almost everyone has a meaning, and sometimes more than one meaning, for the word 'force' and has ideas about the relationship between force and motion. However these meanings and ideas are not necessarily the same as scientists.

Before teaching about force we consider it necessary for all teachers to have an appreciation of the scientists' meaning for force, the typical children's meaning for the word 'force', and an appreciation of the nature of their own meanings for this word. If you have not already done so we would strongly recommend that you read the complementary booklet to this one - "Force, Friction and Gravity" - Notes for Teachers. (Working Paper No. 33)

This Activities Booklet (Working Paper No. 34) provides suggestions for pupil activities which are appropriate for introducing ideas about forces and their relationship to motion at the Form 1-4 level. In our view almost all of the available teacher guide and textbook material make unfounded assumptions about what children already know. The ideas provided here are designed so that pupils first become aware of their own present ideas and how these differ from the basic scientific idea. If this is not done we believe many pupils simply retain their non-scientific views (See Working Paper No. 33).

We hope you find the activities set out in this booklet as useful and as enjoyable to use as we have. In our experience the activities can be used successfully with 11-14 year old children[2]. (See Working Paper No. 32 for the rationale behind these suggested teaching activities and for details of trials of the materials).

Concepts such as work, energy and power are not introduced in this booklet. We believe it is best for children to have obtained a firm grasp of the scientists' concept of force before these other concepts are introduced and developed. We have therefore limited the work here to force, including the force of friction and the force of gravity, and the effects of forces on motion.

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[2] Full page worksheets have been planned for ease of copy.

OVERVIEW OF THE TEACHING PROGRAMME

This teaching programme is split into five parts and is based on our knowledge of the views about force, friction and gravity which we know children bring with them to science classrooms. (See Learning in Science Working Paper No. 33 - Force, friction and gravity: Notes for teachers). We will describe the purposes of the activities in the five parts.

Part 1: Here we want to determine the views about force held by children in a class, and to allow the children to find out that they themselves have a variety of views about the forces. Many pupils think of force as a push or a pull acting on objects (which is correct scientifically) but they also think of it as something in a moving object by virtue of its motion. Physicists prefer to talk about this latter 'something' as the momentum in a moving object: To physicists momentum is not a force. (see p13 of Working Paper No. 33)

Part 2: Many children think that force is something in a moving object, so we build on their intuitive ideas by labelling what they think of as a 'force' in a moving object with its correct scientific label - momentum. Examples are provided of objects gaining and losing momentum.

Part 3: We continue to emphasize the difference between force and momentum. We stress that a force is simply a push or a pull acting on an object. We do this by considering that pushes and pulls cause the momentum of an object to change. These pushes and pulls can be obvious (e.g. a person pushing on a car) or not so obvious (e.g. friction, gravity and reaction forces). However if momentum changes a force must have caused this. We finish this section by re-emphasising that momentum is not a force.

Part 4: In most real life situations there are two or more pushes and pulls acting on an object at the same time. The idea of the total effect of all the pushes and pulls acting on the one object, namely the total force, is introduced. We conclude with the idea that the total force acting on an object determines how the momentum of an object changes with time.

Part 5: This provides an opportunity to check how much the pupils' ideas have been modified by the learning opportunities provided in Parts 2 - 4 above. It also provides a final opportunity for re-teaching the basic ideas.

THE TEACHING PROGRAMME

PART 1: DETERMINING CHILDREN'S VIEWS ABOUT FORCE

The aim of this section[3] is to make pupils and teachers aware that in the everyday use of the word force children have a range of views about what a force is.

ACTIVITIES:

(a) Survey[4]

Give out copies of the survey (Force Survey A - pages 5-7) with answer paper. Have the children answer the survey, and make a copy of their answers so they can refer to responses they made when particular sections are referred to in class. It is important that you as the teacher analyse carefully the way pupils have responded to the questions as this will help you in teaching this section of work.

Do not go over the survey with the class as this stage but keep a record of pupil results. This will be needed in Part 5.

(b) Discussion

Worksheet A is designed so that pupils can explore the range of views they and other pupils hold about the word force. Individual consideration of these situations, can be followed by small group discussion, and possibly class discussion. If consensus view is different from the scientists' view this can be returned to later in the series of lessons.[5] A low key role on the part of the teacher is vital in this discussion. Questions such as:

"Who can put that another way? Do so."

"Who disagrees with _____? Explain why to the rest of us."

"Do these forces you are talking about have directions?"

"Using arrows to show us the directions of the forces, come and show us about _____ on the blackboard."

The idea at this stage is to make pupils aware of the variety of views held about force, and that there is a need for the following series of lessons.

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[3] The Parts of this unit are not equivalent regarding the time spent on them. e.g. the two activities here can be completed within an hour.

[4] The scientists' responses to the survey questions are given in Appendix A. You may wish to check these after you have first attempted the survey yourself!

[5] That is why a fourth column is there - for the scientists' view. In one trial pupils gave four different combinations of individual forces (with labels such as movement, balance, wind, drag, gravity) for the forces involved in Question 3 of Worksheet A. For an idea of the views children are likely to hold see Working Paper No. 33.

FORCE - SURVEY A

What to do:

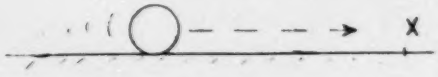
On a sheet of paper
1. write your name
2. write the numbers 1 to 10 in a column down the page.
3. beside each question number, write the letter, or letters that correspond to your answers.

1. Which of these words give the best idea of force?
(you can choose more than one)

(a) push (b) pressure (c) pull
(d) energy (e) momentum (f) motion

2. A ball is rolling along a flat table. It slows down and stops at X. Which of these could explain this? (choose one)

(a) The ball ran out of force
(b) The ball just stopped naturally
(c) Friction caused the ball to stop
(d) Gravity caused the ball to stop



3. A skate board rider is moving down a gently sloping path. The person is going at the same speed all the time. She is not getting faster or slower.

Moving at a steady speed.
Not speeding up or slowing down.

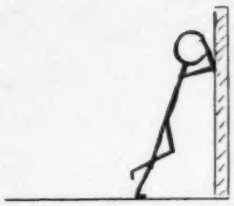
Which of these sentences about the total force on the rider is correct?

(a) There is no total force on the rider because her speed is steady
(b) There must be a total force on the rider because she is moving

4. A boy holds a ball steady in the palm of his hand. He drops his hand away from the ball very quickly. Just after he lets it go, but before it has really started to drop down, would there be a force on the ball?

(a) No, it's not moving yet
(b) Yes, there is gravity

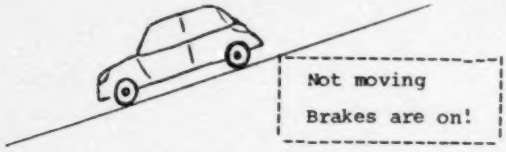
5. A person in leaning against a brick wall.
Is the person putting a force on the wall?



(a) No

(b) Yes

6. A car is parked on a hill. It is not moving.



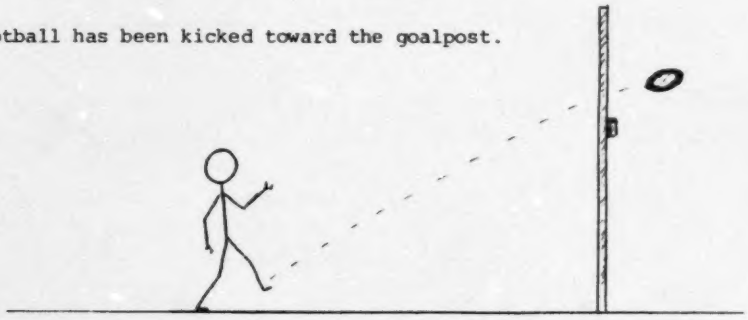
Which of the following is correct?

(a) There are many forces on the car but the total force is zero

(b) There are many forces on the car and the total force is downwards

(c) There are no forces on the car at all

7. A football has been kicked toward the goalpost.



As it moves through the goalpost what are the forces on it?
(you can choose more than one)

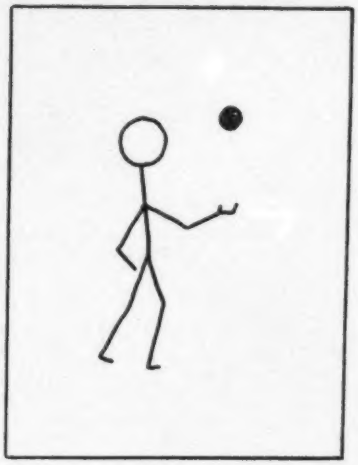
(a) The force of gravity

(b) The force of friction

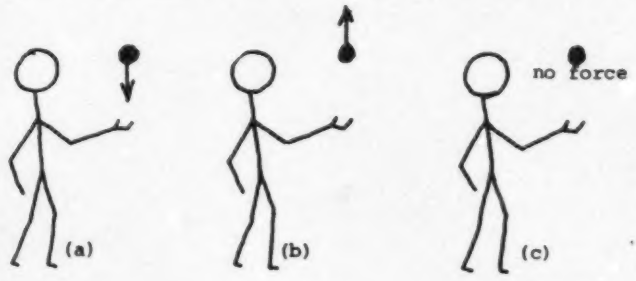
(c) The force of the kick

8 - 10. A person throws a tennis ball straight up into the air just a small way.

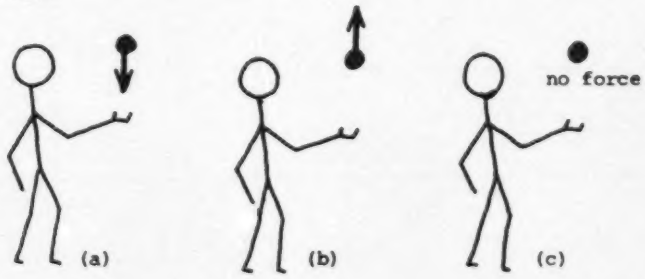
The questions are about the total <u>force</u> on the ball.



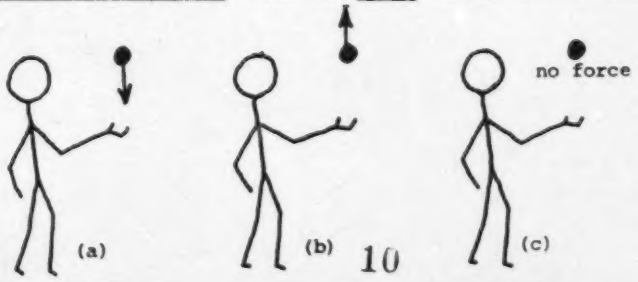
8. <u>If the ball is on the way up</u>, then the <u>force</u> on the ball is shown by which arrow?

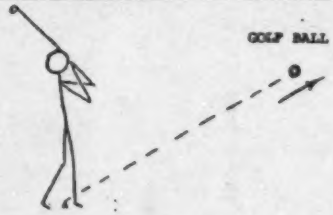
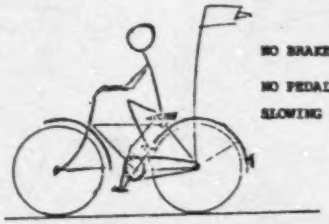
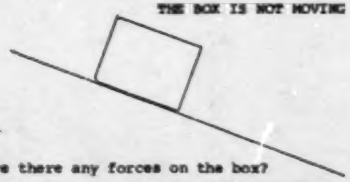


9. <u>If the ball is just at the top of its flight</u>, then the <u>force</u> on the ball is shown by which arrow?



10. <u>If the ball is on the way down</u>, then the <u>force</u> on the ball is shown by which arrow?



	YES/ NO	WHY YOU THINK THAT WAY — YOU	WHY YOU THINK THAT WAY — GROUP	
1  Are there any forces on the golf ball?				
2 Are there any forces on the golf ball?				
3  Are there any forces on the bicycle?				
4  Are there any forces on the box?				

PART 2: MOMENTUM AND MOMENTUM CHANGES

This part aims to:

* attach the term momentum to the intuitive view that most pupils have regarding moving objects, and to make pupils familiar with the term momentum. (Activity 2.1).
* show there is a relationship between momentum and size (mass) and speed (velocity). (Activity 2.2 - can be omitted for F1/2 pupils)
* enable pupils to describe the movement of typical everyday objects losing and gaining momentum. (Activities 2.3-2.4; Worksheets B and C).

2.1 Formal Lesson on Momentum

(a) Have Fig. 1 and 2 on blackboard or OHP.

Look at these trucks.
Which would be harder to stop?
Why?
(An answer such as "Truck B has more force in it" is not right. Scientists have a term for what that pupil is thinking about. They would say Truck B has more momentum)

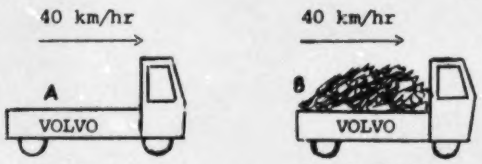


Fig. 1

(b) Ask similar questions for the cars in Fig. 2. (Again Car A is more difficult to stop as it has more momentum. Momentum is not a force).

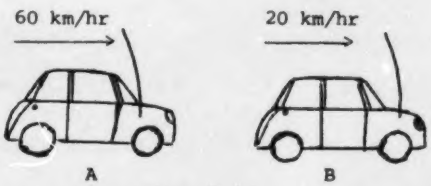


Fig. 2

(c) Copy:

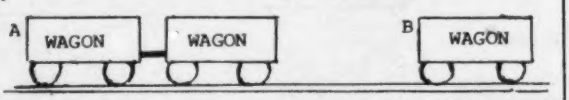
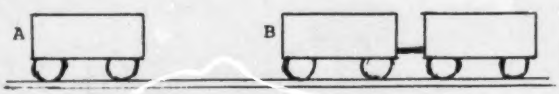
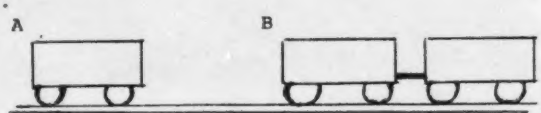
M O M E N T U M : something which all moving things have

- things that move have momentum.
- things that are not moving have no momentum
- big things have more momentum than small things moving along at the same speed. (Copy Fig. 1 down).
- cars moving at high speed have more momentum than cars moving at slow speeds. (Copy Fig. 2 down)
- a big thing moving fast has a lot more momentum than a small thing moving slowly.

2.2 Teacher-led Discussion and Worksheet (Can be omitted for F1/2)

Copy and allow children to complete (answers to these and other worksheets are given in Appendix C).

MOMENTUM

	Does A or B have more momentum?	How much more momentum?
1. Car A and Car B are the same type of cars - (Minis)		
2. 		
3. 		
4. 		

N.B. : You may like to use P.S.S.C. trolleys to demonstrate the points made above

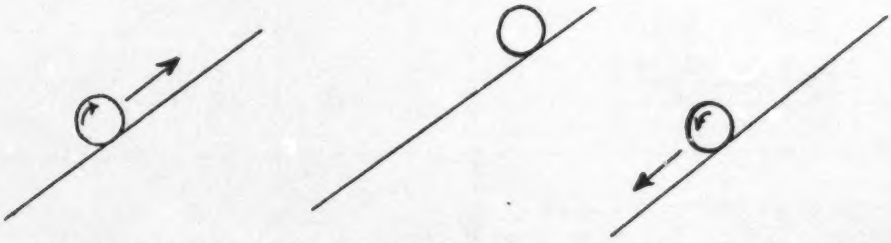
: For the more able F3 and F4 pupils, the ideas of momentum might be quantified by using Part 1 of Extension 1 in Appendix B.

2.3 Worksheet B

Losing and Gaining Momentum

Complete the sentences below.

1. Roll a ball up a slope at least three times. Watch carefully what happens.

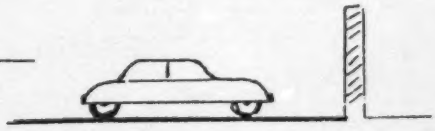


A ball rolling up a hill is slowing down. It is _____ (gaining/losing) momentum.

When the ball has stopped moving it _____ (has/has no) momentum.

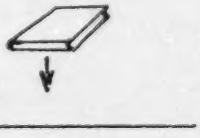
As the ball rolls down it is speeding up. It is _____(gaining/losing) momentum.

2. If a car hits a brick wall it _____ (gains/loses) momentum very quickly.



3. As the tyres push against the road a car with a powerful engine can _____ (gain/lose) momentum very quickly.

4. A falling book _____ (gains/loses) momentum as it falls but _____ (gains/loses) it very quickly when it hits the ground.



5. What happens to a trolley after the pusher has stopped pushing? Use the word 'momentum' in your answer.

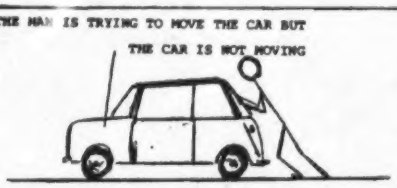
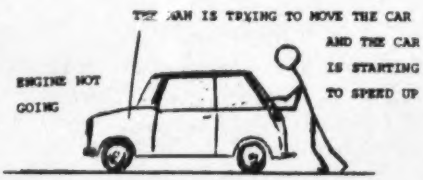
_____

_____

_____

_____

2.4 Worksheet C

	Does the _____ have momentum? Yes/No	Is the momentum changing? Yes/No	If the momentum is changing describe how it is changing
1 			
2 			
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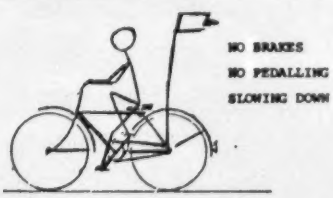
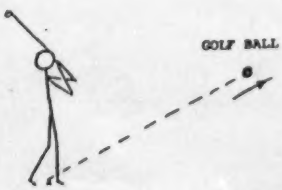
4 			
5 			

PART 3: PUSHES AND PULLS

The aim of this section:

* to introduce pupils to the terms pushes and pulls as the things that cause changes in momentum and to provide them with everyday examples. (Activity 3.1)
* to introduce force as an alternative name for push and/or pull and to point out that momentum is not considered to be a force. (Activity 3.2)
* to introduce gravity, friction and reaction forces as mysterious pushes and pulls that account for some momentum changes. (Activity 3.3-3.6)
* to distinguish quite clearly the difference between the force on an object from the momentum of an object. (Activities 3.7 and 3.8)

ACTIVITIES

3.1 This activity involves some situations where momentum is changing and where these changes are caused by obvious pushes or pulls (initially disregard the effects of friction - this comes later. Focus attention on what happens during the push/pull.) The activity is designed to lead to the idea that pushes and pulls produce momentum changes, but that momentum is not considered to be a push or a pull.

Questions / Instructions	What happens while the person and object are in contact?	Has the momentum increased/decreased/ stayed the same?
1. Give a trolley which is not moving a push.		
2. Pull a trolley which is not moving.		
3. Give a slow moving trolley a shove from behind.		
4. Kick a ball.		
5. Set off on a bicycle.		
6. Allow a moving trolley to hit something. (be careful!)		
7. Push a moving trolley from the front.		
8. Let a moving ball hit a brick/block wall.		
9. Catch a ball thrown by someone else.		
10. Catch and pull back on a cycle being ridden by a pupil.		

N.B. (a) F1/2 pupils can use a homemade trolley or one from the library. F3/4 pupils have P.S.S.C. trolleys as a possibility.

(b) Once the above chart has been filled in, put this heading. "What caused the momentum to change?" ('Push' or 'Pull' can be filled in where suitable)

(c) CONCLUSION: Pushes and Pulls cause the momentum of objects to change but momentum is not a push or a pull.

3.2 FORCE as an Alternative Name for Pushes and Pulls

The word force may have been used in the discussion as an alternative to the words push or pull. This is fine as long as it is realised force has other meanings as well, in a non-scientific sense but these other meanings are not appropriate in this study of force.

Discuss with Class:

Force is a familiar word to us all.

We talk of the police force.

We talk about "we had to force him to do it".

We talk about the force being with you. (Star Wars)

We talk about the force in a jet of water.

These ways of using the word force are quite different to the way a scientists uses the word force.

Copy into Books

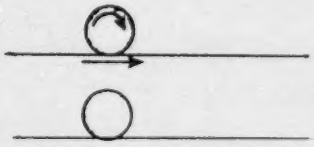
> Just those things we have been calling pushes or pulls scientists call forces. Forces can change momentum but scientists do not think of momentum as a force.

3.3 Momentum not Changing

What's happening if the momentum is not changing? [This Section (3.3) involves situations where the effects of friction are minimal or there is no friction.]

Instructions:

1. Roll a ball along a smooth horizontal surface (a marble is best).
2. Place a ball on a horizontal surface.
3. Allow a glider to move steadily along an air track (if available).



Questions for Discussion:

1. What happens to the object in each case? (They hardly change speed at all)
2. What is happening to its momentum? (It is not changing)
3. If momentum doesn't change what can we say about the force on the object? (It is zero. Momentum is not a force)

These lead to the important idea:

> If there are no pushes or pulls acting the momentum is not changing.

If some pupils point out that sometimes when pushes and pulls act there is no momentum change (e.g. immovable objects) it might be hinted that may be there is other pushes and pulls also acting, in the opposite directions, and we will consider these later. (Part 4).

3.4 - 3.7: Mysterious Pushes and Pulls

The force of gravity (3.4, 3.5) the force of friction (3.6) and reaction forces (3.7) are identified here. Other forces such as magnetic and electrical forces are not mentioned at this stage.

3.4 Falling Objects

Initially we consider only falling objects, where the objects gain momentum because of the force of gravity.[6] The idea is to lead pupils to the view that as the momentum is changing there must be a force on the object. We call this mysterious force which we can't see the force of gravity; a downwards pull (relate to Section 3.1 where objects increase their speed).

Discussion:

Drop a small object several times from 2 m to the floor.

Questions:

1. What is the object doing before being released? (Not moving)
2. What is it doing just after being released? (Hardly moving)
3. What seems to be happening as it falls? (Speeding up)
4. Has the momentum changed? (Yes it is increasing)
5. What caused this? (There must be a force acting downwards)

> We will call this force that we can't see the force of gravity.

3.5 Objects Slowing Down Because of the Force of Gravity

Many children believe that when a ball is thrown upwards, the direction of the force is upward. The purpose of this activity is to clarify this confusion by focussing on what happens before the object starts to fall downwards

Questions \ Instructions	A ball thrown straight upwards	A ball kicked straight upwards	A ball headed straight upwards
1. When do you stop giving the ball a push?			
2. What happens to the ball when it is no longer touching the person?			
3. How is its momentum changing after leaving the person?			
4. What causes its momentum to change after leaving the person?			
5. In which direction is this "thing" that causes the momentum of the ball to change?			

[6] The term force of gravity is used in preference to just gravity since the latter term is scientifically vauge. Refer to the Section 5.1 of Force, friction and gravity: Notes for teachers (LISP, Working Paper No. 33).

[7] In all the cases shown the momentum changes occur because of the force of gravity pulling down on the object. There would also be friction with the air but that would be a small force.

3.6 Frictional Forces

The idea of frictional forces is clarified in the following section. Situations involving momentum changes caused by friction only are used. Focus on what happens after the contact push has ceased.[8]

Activities:

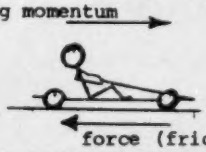
Worksheet

Instructions / Questions	What happens after you have finished pushing?	Has momentum increased/ decreased/stayed the same (for the underlined object)
1. Push a trolley.		
2. Slide a block of wood along the floor.		
3. Riding along on a bicycle on a flat road.		
4. Riding along on a skateboard.		
5. Push a small boat across the water in a swimming pool.		

Questions:

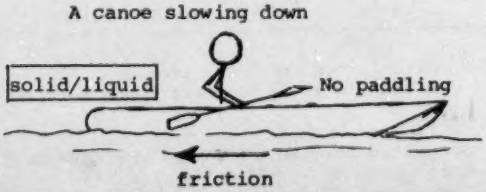
(a) What has caused the momentum to change?

(b) What is the direction of this force (push, pull)?

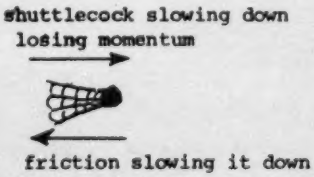


[8] In all these cases the momentum has decreased because of the force of friction in the opposite direction. The most common instances of where friction acts are when two solid surfaces tend to slide, or are sliding, over each other. However, friction can also act when other combinations of surfaces are in contact.

A canoe slowing down



solid/gas



PRACTICAL ACTIVITY FOR 3.4 - 3.6 (Friction and Gravity)

Comparing Forces (Push/Pulls) and Momentum

i) Go outside and practice shooting for goal with a ball. Pupils to describe motion using terms changes in momentum/pushes/pulls/forces. (friction and gravity).

ii) Push a pupil who is on a skateboard. Pupils to describe precisely what they see. Repeat several times. Do the same on two or three different surfaces. Pupils account for differences. On blackboard draw:

He starts from rest
He is given a push
He gains momentum
Force is forward

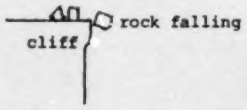
He is slowing down
There is a push (friction) against him
He is losing momentum
Force is backward

He stops
He has no momentum
Force is zero

3.7 Worksheet

Pushes, Pulls and Momentum

Copy three (or more) of these examples. Complete the sentences.

1. 

The rock is _____ (gaining/losing) momentum as it falls.
The rock _____ (gains/loses) momentum because of the force of gravity.

2.

As the ball is kicked, it quickly _____ (gains/loses) momentum while it is being kicked.

3.

A person throws a brick upwards. It gets a _____ (push/pull) in the _____ (same/opposite) direction as it is moving, after it has left the person's hand.

4.

A skater is slowing down, she gets a push/pull because of _____
_____
_____

5.

The motor of a motor boat has just been turn off. The boat _____ (gains/loses) momentum because of
_____
_____

6.

A stone as it starts from a catapult is _____ (gaining/losing) momentum, because of the force of the catapult.

Extra: Draw in arrows to show the pushes or pulls that are causing the momentum changes.

NOTE: When momentum is increasing, the force is in the direction of motion.
When momentum is decreasing, the force is in the direction opposite to the direction of motion.

3.8 Reaction Forces (could be omitted with F1/2 pupils at this stage)

Many children have a great deal of difficulty appreciating that a solid non-moving object like a wall or a concrete path; can push on an object. This activity attempts to introduce this idea, by following through the idea that there must be a force to produce a momentum change.

	Is the momentum changing?	Is there a force on the object?
1. A car collides with a solid wall.		
2. A ball hits the ground.		

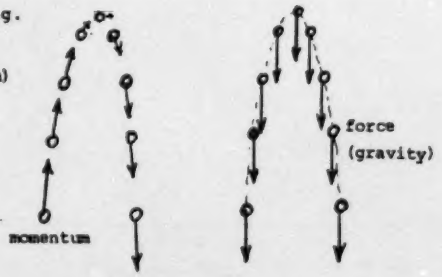
We call the force provided by the wall, and the ground, in the above cases a reaction force.

3.9 Summary: The Differences Between Force and Momentum

(a) Pupils need plenty of opportunity to draw diagrams to show the similarity and differences between these terms for many situations, e.g.

i) Ball thrown upwards (ignoring friction)

(length of arrows shows size of the momentum and force)



ii) A trolley slowing down

(b) It may be useful to return to 2.4 Worksheet C and get pupils to draw in all the individual forces (for example see Appendix B of Notes for Teachers, Working Paper 33)

Summary

If a body is changing its momentum then there must be a force on the body.

Momentum is not a force, but forces can produce changes of momentum.

Extension: For more able F3 and F4 pupils the above ideas could possibly be quantified. See Appendix B, Extension 1(ii).

Practical Activities: Various practical activities for F3 and F4 pupils could be introduced here. See Appendix B, Extension 2.

PART 4: TOTAL FORCE

This section aims

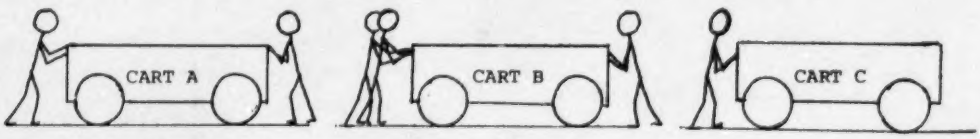
* to introduce the idea that when there are a number of forces (pushes and pulls) on an object the total effect of these pushes and pulls is called the total force (Activity 4.1).
* to introduce the idea that provided we define total force suitably, it is related to the momentum change (Activity 4.1 and 4.2).
* to clarify the relationship between individual forces, total force and momentum change, e.g. zero total force results in no change of momentum; a change of momentum means that the total force is non-zero (Activities 4.3 and 4.4).

4.1 Teacher-Led Discussion on OHP or Blackboard

In most everyday examples there are several pushes or pulls on an object. We consider the total push (or pull) as the total force. These terms are clarified below.

(a) Total Force

Many things often have more than one push acting on them at once.



Equal and opposite pushes - no movement

Unequal pushes
The trolley will start to gain momentum

What is the total push on Cart A?

That depends what we mean by total push.

We add them up and say there were two pushes on it

OR

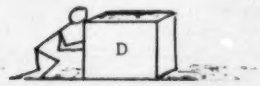
We could say that as the pushes are equal but opposite in direction, the total push on Cart A is zero.

Scientists find it useful to say that the total push on Cart A is zero. That is, the total effect of the two forces is zero. This idea fits in with our idea that there is no momentum change in this case.

They would also say that the total push on Cart B is the same as the total push on Cart C! In B, the push from the right is equal and opposite to one of the pushes from the left side, so the total effect on whether the cart would change momentum or not is the same. Therefore Carts B and C would gain momentum (to the right).

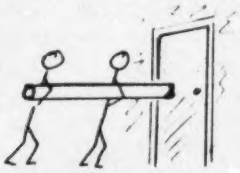
(b) Invisible Pushes and Pulls

Sometimes the total push is zero even though it doesn't look like it.



Box will not slide

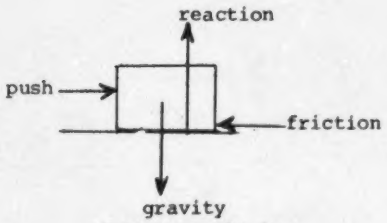
Suitcase will not lift up



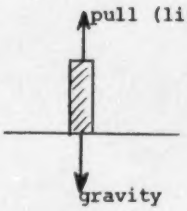
Ram will not go through door!

In these cases there are invisible pushes and pulls (friction on Box D, gravity on suitcase E and a reaction force on Wall E), so that the total push (or pull), i.e. the total force is zero. Of course there are vertical gravity and reaction forces as well.

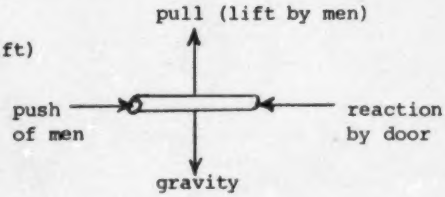
These situations can be represented symbolically:



forces on the box



forces on the suitcase



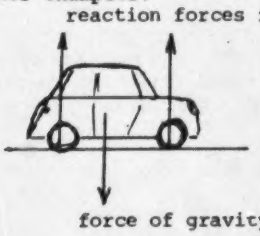
forces on the ram

However note:

1. The friction force (under any set of conditions) has a maximum value and if the push is bigger than this, then a momentum change will occur. Therefore the total force would not be zero.

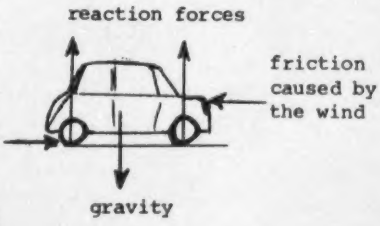
2. You can think of the reaction force generally as a supporting force to stop things (and people) falling through the floor, through tables, through the ground, or through walls.

Other examples:



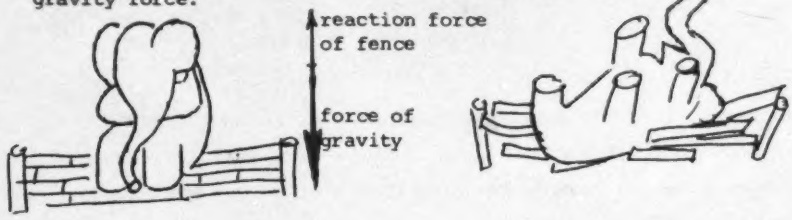
parked on the road

motor causes wheels to try to spin, friction of road stops spinning and puts a force on the car.

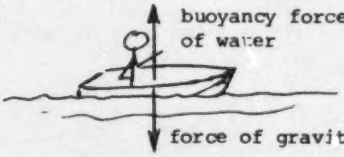


Car speeding up

3. The reaction force does not or cannot always be equal and opposite to the gravity force.[9]



4. The reaction force is not always provided to a solid surface.



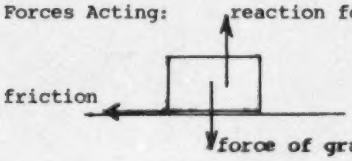
If the buoyancy force of water is less than the force of gravity the boat sinks!

(d) Considering all the Forces (Pushes/Pulls)

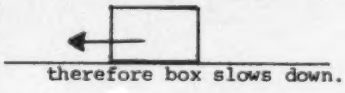
If we consider all the pushes and pulls on an object we can determine if there is a total force on an object.

Eq. 1 a box sliding along the floor in ⟶ direction.

Forces Acting:



Total force is not zero



However we have another way of working out if there is a total force on an object. We can consider if the momentum is changing.[10]

Checklist for Total Force

A simple check to find out if there is a total force on an object is to ask:

"Is the momentum changing?"

If YES, then the total force is not zero.
If NO, then the total force is zero.

[9] The terms balanced forces/unbalanced forces are dubious terms to use. The term balanced forces implies that the total force is zero, while unbalanced forces implies a non-zero total force. If you feel you must talk about balanced and unbalanced forces, cultivate the habit of saying "the forces balance/do not balance". or "the forces are balanced/not balanced". This describes a state of existence involving forces rather than a type of force which the adjective unbalanced suggests.

[10] While momentum can change by increasing or decreasing in a particular direction it can also change by changing direction. There is a total force on a satellite pulling it toward the centre of the earth. The direction of the momentum is continually changing and it moves in a circle.

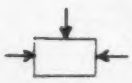
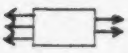
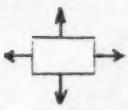
To determine if the momentum is changing it must be compared at two different times. This is why a vertically thrown ball can have changing momentum at the top of the flight even though it has zero momentum for an instant. Despite the zero momentum for an instant we say the momentum is changing. (Refer to questions 2-5, 8-10 of survey A).

4.2 Worksheet

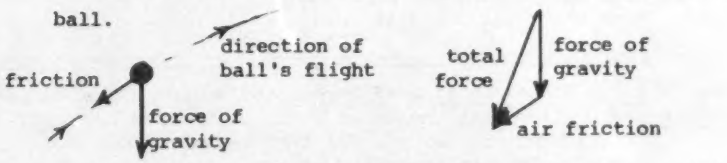
The diagrams below show equal sized forces (pushes/pulls) acting on objects. Work out which forces total to zero and mark what is left on the diagram opposite. An example has been done to show you what to do. Copy and complete:

	Separate forces	Total force	Would there be a momentum change?
e.g.			
(a)		same as	Yes

Now try these:

(b)		same as	
(c)		same as	
(d)		same as	
(e)		same as	
(f)		same as	

Extension: Some pupils may wish to know how to find the total force when individual forces are in different direction, e.g. golf ball.

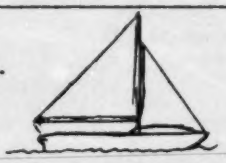
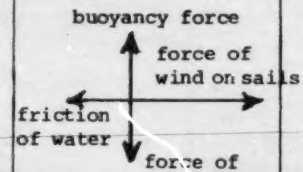


In these cases, we add the arrows together (head to tail)

4.3 Worksheet

For the situations below, use arrows to show the individual forces acting and answer the questions.

The first one is done for you.

	Separate forces	Is the momentum changing?	Total Force
1.  Yacht blown by the wind speeding up.		Yes	
2. On skateboard, slowing down.			
3. Box and parachute falling at steady speed.			
4. Man trying to shift heavy crate (No success)			

The forces acting on the examples of Worksheet 4.2 are identical to the examples given in Appendix A of Working Paper No. 33.

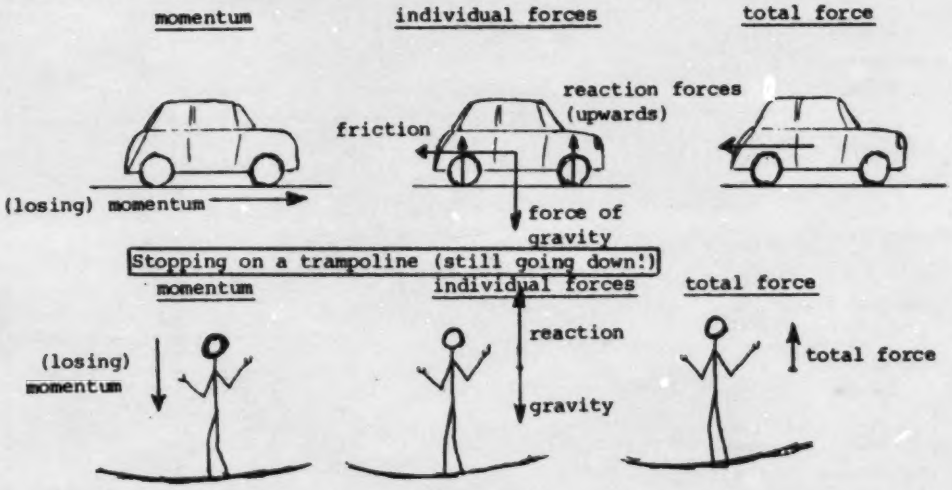
Worksheet 4.2	Appendix A Working Paper No. 33
Skateboard	Bike
Box and Parachute	Bowl (except steady speed is vertical)
Heavy Crate	Car I

Worksheet 4.2 could be extended by pupils making up their own examples, or by using further examples from Appendix A of Working Paper No. 33.

4.4 Grand Summary: Momentum, Individual Forces, Total Force

Again, pupils should have plenty of opportunity to draw diagrams to show clearly that they understand the terms momentum, individual forces, and total force and appreciate the differences between them.

Example: Car slowing down (motor not going)



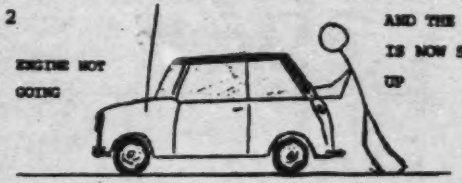
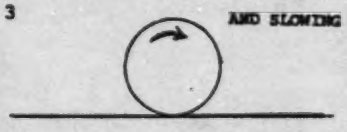
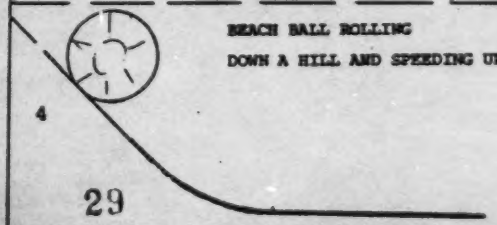
Individual forces add together to give the total force.

The total force causes the momentum to change.

NOTE: zero total force means the momentum will not change

total force in the direction of motion means momentum will increase

total force in the opposite direction to the direction of motion means momentum will decrease

	YES/ NO	WHY YOU THINK THAT WAY		What is the total force on the _____? (zero/not zero)
		YOU	GROUP	
1 THE MAN IS TRYING TO MOVE THE CAR BUT THE CAR IS NOT MOVING Are there any forces on the car?				
2 THE MAN IS TRYING TO MOVE THE CAR AND THE CAR IS NOW SPEEDING UP ENGINE NOT GOING  Are there any forces on the car?				
3 BOWL ROLLING ON A BOWLING GREEN AND SLOWING DOWN  Are there any forces on the ball?				
4 BEACH BALL ROLLING DOWN A HILL AND SPEEDING UP  Are there any forces on the beach ball?				

PART 5: INVESTIGATING HOW CHILDREN'S VIEWS HAVE CHANGED

The aim of this section is to

* investigate how individual children's ideas have been modified by the learning experiences provided in this unit of work.
* provide the opportunity for further remediation if necessary.

Activities:

(a) Survey B

This is a parallel form to Survey A although this fact should not be pointed out to pupils until after they have answered the survey. Pupils make a copy of their answers for reference before handing in their answer sheets.

(b) Checking on Changes

Compare pupils' answers in Survey A and Survey B (See Appendix A). It is desirable to return both Survey A and Survey B to pupils to let them check how their answers have changed.

Go over the survey questions with pupils, reteaching points where necessary.

> In our view this is a most important aspect of the topic, as this learning experience can have a most significant effect on pupils who still have non-scientific views.

Collect back Survey questions and answers.

(c) Rechecking on Changes

We would strongly recommend that either Survey A or B is used again with the pupils in a surprise test 3-6 months after the topic is complete.

Survey B

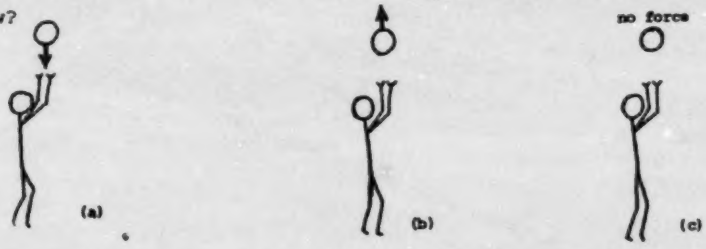
What to do:

On a sheet of paper:

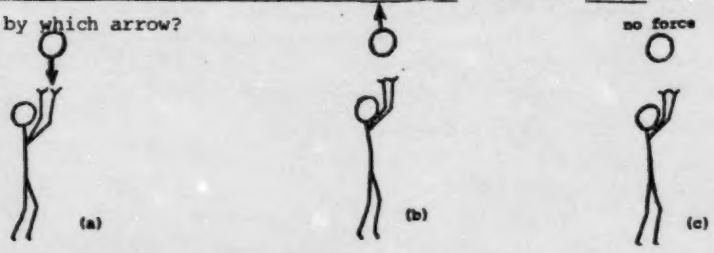
1. Write your name.
2. Write the numbers 1-10 in a column down the page.
3. Beside each question write the letter, or letters that correspond to your answers.

1-3 A netball player sends a ball straight up into the air just a small way. The questions are about the total force on the ball.

1. If the ball is on the way up, then the force on the ball is shown by which arrow?



2. If the ball is just at the top of its flight, then the force on the ball is shown by which arrow?



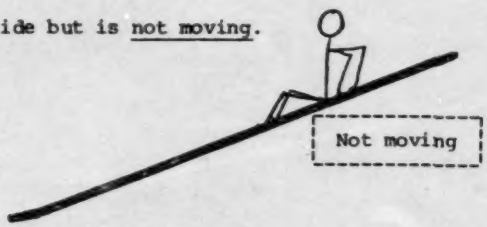
3. If the ball is on the way down, then the force on the ball is shown by which arrow?

4. A soccer ball is kicked into the goal.

As it moves into the goal what are the forces on it?
(you can choose more than one)

(a) The force of the kick
(b) The force of gravity
(c) The force of friction

5. A person is on a slide but is <u>not moving</u>.



Which of the following is correct?

(a) There are many forces on the person but the total force is zero
(b) There are many forces on the person and the total force is downward
(c) There are no forces on the person at all

6. A diver steps off the end of a diving board very gently and slowly.

Just after she has stepped off, but <u>before she really started to drop down</u>, would there be a force on the diver?

(a) Yes, there is gravity
(b) No, she is not moving

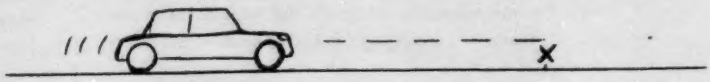
7. A person is leaning against a building. Is the person putting a force on the building?

   (a) Yes
   (b) No

8. Which of the following words give the best idea of force?
   (you can choose more than one)

   (a) motion (b) momentum (c) energy
   (d) pull (e) pressure (f) push

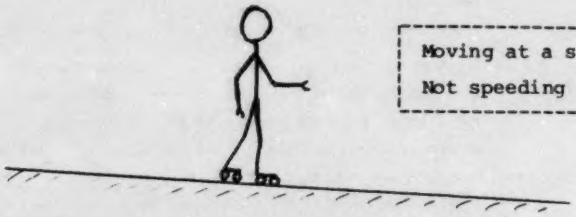
9. A car is travelling along a flat road when the engine stops going. The car slows down and stops at X.



   Which of the following could explain this? (choose one)

   (a) Gravity caused the car to stop
   (b) Friction caused the car to stop
   (c) The car just stopped naturally
   (d) The car ran out of force

10. A person on roller skates moves along a gently sloping path. The person is going at the same speed all the time. She is not getting faster or slower.



   Moving at a steady rate.
   Not speeding up or slowing down.

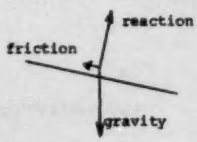
   Which of these sentences about the total force on the skater is correct?

   (a) There is no total force on the skater because her speed is steady
   (b) There must be a total force on the skater because she is moving

APPENDIX A

A scientist's answers to the Survey A questions (Note that Survey A and B have equivalent questions, although they are in a different order and for some questions even the position of the correct alternative has been altered).

For fuller explanations you should refer to the Notes for Teachers Paper (Working Paper No. 33).

Survey A. Q.1 (Survey B. Q.8	a, c d, f)	A force is a push or a pull that may involve contact (e.g. a person sitting on a chair experiences the pull or force of gravity. The chair pushes back (reaction force). If it did not support the person or push back, the person would fall through the chair.) Pressure is force per unit area and although related to force is not considered by physicists to be a force. For example the same force (a person's weight) can put different pressures on a small section of vinyl flooring (depending on whether stilleto or flat heels are being worn).
Survey A. Q.2 (Survey B. Q.9	c b)	There is only one force acting on the ball in the horizontal direction - that of friction. Friction is in the opposite direction to the ball slowing it down.
Survey A. Q.3 (Survey B. Q.10	a a)	Because the speed is steady there is no change in momentum; therefore there is no total force. In this case there are three forces acting. They are the force of gravity, friction, and the reaction force from the road on the skateboarder. The directions of three forces can be shown. They add to zero (see p.22 extension) 
Survey A. Q.4 (Survey B. Q.6	b a)	The force of the earth's gravity always acts downwards on objects near the earth (e.g. ball, or spacecraft).
Survey A. Q.5 (Survey B. Q.7	b a)	Refer back to Q.1.
Survey A. Q.6 (Survey B. Q.5	a a)	Because the car's momentum is not changing the total force is zero. (Refer to p. 21) There are three forces on the car as explained in Q.3.
Survey A. Q.7 (Survey B. Q.4	a, b a, b)	The force of gravity pulls the ball towards the earth. It doesn't fall immediately to the earth because it gained momentum (momentum is not a force) when the person was actually kicking it. The friction between the ball and the air has the effect of slowing the ball in the direction it is moving. There is no force of the kick in the position shown. The force of the kick ended the second the ball left the player's boot.
Survey A. Q.8-10 (Survey B. Q.1-3	a, a, a a, a, a)	Force is basically a push or pull acting on an object. In this case there is only one significant force on the ball, the force of gravity which is a constant force acting on the ball at all times in a downward direction. Its effect is to slow down the ball moving upwards until it becomes momentarily stationary. Even at that instant, the force of gravity acts. Since this force continues to act, the ball falls, speeding up as it does so. (Another force, that of friction between the ball and the air, acts on the ball opposite to the direction of its motion while it is moving. In this example the speeds reached are not large. Hence friction will be negligible compared to the force of gravity, and will not significantly affect the ball's motion).

APPENDIX B: EXTENSION MATERIAL

EXTENSION 1

FORCE, MOMENTUM AND PLAYING WITH NUMBERS - If you like Mathematics only!

How quickly the momentum of something changes depends on how big the force is.

A big force will cause the momentum to change quickly. For example as you kick a football hard.

Also if the momentum changes quickly there must be a big force. For example if a car runs into a brick wall and stops suddenly then the car has been acted on by a big force provided by the wall.

If you are good at mathematics you might find it helpful to know

i) $\left\{\begin{matrix}\text{the momentum of} \\ \text{an object}\end{matrix}\right\} = \left\{\begin{matrix}\text{the mass of} \\ \text{the object}\end{matrix}\right\} \times \left\{\begin{matrix}\text{how fast it} \\ \text{is travelling}\end{matrix}\right\}$

so a car of 1000 kg travelling at 20 m/s has a momentum of 20,000 kg m/s!

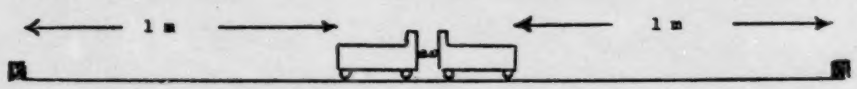
ii) $\left\{\begin{matrix}\text{force on an} \\ \text{object}\end{matrix}\right\} = \left\{\begin{matrix}\text{change in} \\ \text{momentum} \\ \hline \text{time taken}\end{matrix}\right\}$

so if the 1000 kg car travelling at 20 m/s hits a wall and stops in 1 second then the force on the car is $\frac{20,000}{1}$ = 20,000 Newtons.

EXTENSION 2

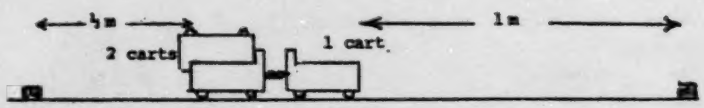
LET'S DO AN EXPERIMENT ABOUT MOMENTUM

1. Explosion 1



Which trolley will hit the bumper first do you think?
Do the experiment.
Which cart had the greatest momentum?

2. Explosion 2



Which trolley will hit the bumper first do you think?
Do the experiment.
Which cart had the greatest momentum?

3. Thinking!
As the carts were pushed apart by the springs they gained momentum. Which cart, or set of carts, gained the most momentum as the spring pushed on them? Which cart, or set of carts, had the greatest force on it?

4. Force Measures
Many textbooks and Resource Units (e.g. Effects of Forces, Teacher Trial Resource Unit 4/42, Department of Education, 1981; Force, Motion and Mass, Trial Guidelines, Form 3-4, Department of Education, 1980) have useful activities on Force Measurers. These are well worth using.

APPENDIX C

Answers to Worksheet Questions

2.2

1. A; three times as much momentum as B.
2. A; twice as much momentum as B.
3. They both have the same amount of momentum; _____
4. B; four times as mucy momentum as A.

2.4

1. No; no; _____.
2. Yes; Yes; the car is gaining momentum as it speeds up.
3. Yes; No; _____.
4. Yes; Yes; the bike loses momentum as it slows down.
5. Yes; Yes; the ball is slowing down because of the friction between the ball and the air also the momentum is decreasing and changing direction because of gravity.

3.1

1.	The trolley quickly speeds up;	increased;	push in the direction of motion.
2.	The trolley quickly speeds up;	increased;	pull in the direction of motion.
3.	The trolley quickly speeds up;	increased;	push in the direction of motion.
4.	The ball begins to move very fast;	increased;	push in the direction of motion.
5.	The bicycle starts moving;	increased;	push in the direction of motion.
6.	The trolley slows down (or stops);	decreased;	push in the direction opposite to the motion.

(Some pupils find it difficult to think of a wall or something, actually pushing on the trolley. This is discussed further in Section 3.7).

7.	The trolley slows down (stops);	decreased;	push in the direction opposite to the motion.
8.	The ball stops (initially);	decreased;	push in the direction opposite to the original motion.
9.	The ball slows down (stops);	decreased;	push in the direction opposite to the motion.
10.	The cycle slows down (stops);	decreased;	pull in the direction opposite to the motion.

3.3

i) It hardly slows down at all.

ii) It is not really changing.

iii) It is zero. Note: momentum is not a force.

3.5

The answers apply for all three examples:

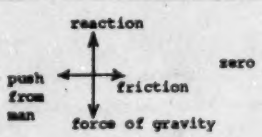
1. When you are not touching it.
2. It gradually slows down, as it goes upwards.
3. It is getting less.
4. The pull of gravity.
5. Downwards.

3.6

In all these cases the momentum has <u>decreased</u> because of the force of friction in the opposite direction.

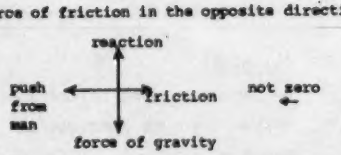
4.5

1. Yes



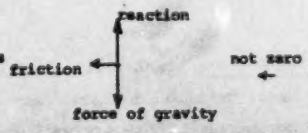
zero

2. Yes



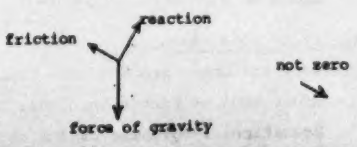
not zero

3. Yes



not zero

4. Yes



not zero